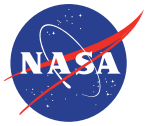

Jet Propulsion Laboratory
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JPL Cleanroom Practices and Protocols

T. Arakelian and J. Benardini, Jet Propulsion Laboratory, 2017

Government sponsorship acknowledged.

JPL Cleanroom Practices and Protocols

Jet Propulsion Laboratory

- Has over 100 cleanrooms
- Varies from ISO 1 to ISO 8.5

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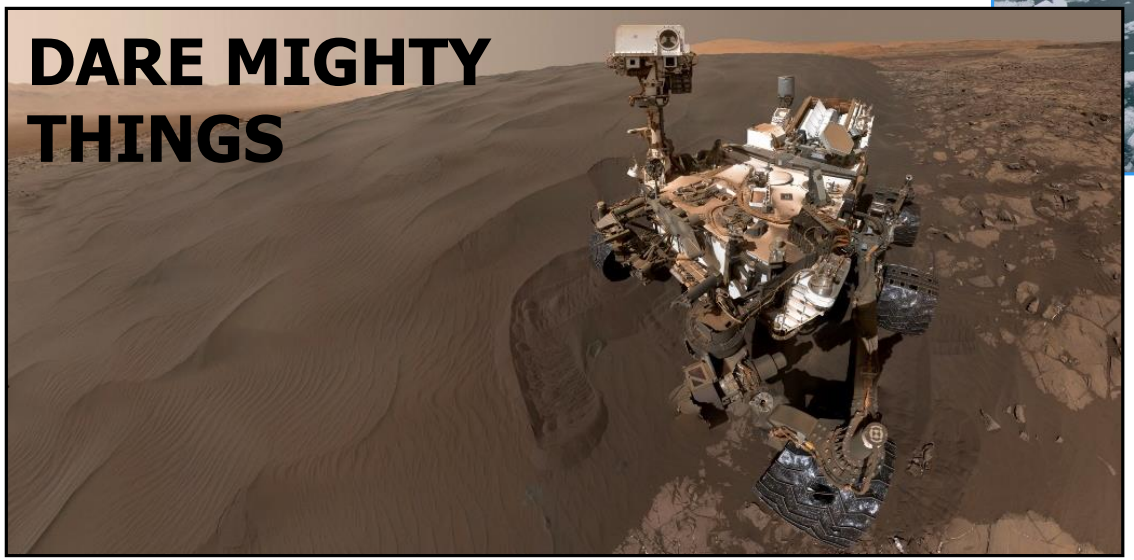
JPL Cleanroom Practices and Protocols

Some are for research

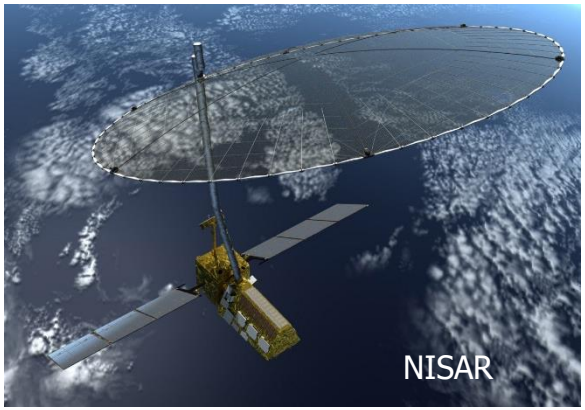


Others are for spacecraft and instrument assembly

Making uniform Contamination Control (CC) requirements complex and difficult

JPL Cleanroom Practices and Protocols

Some spacecraft slated to study the Earth



Others will explore bodies that have the possibility of harboring alien life

With varying CC requirements, and additional Planetary Protection (PP) requirements for some

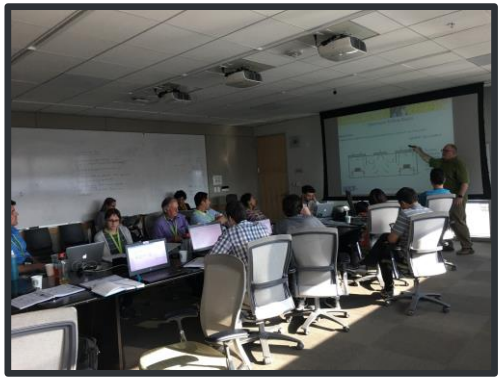
JPL Cleanroom Practices and Protocols

Technical Facilities Management (TFM)

- Team of scientists, engineers, technicians and administrative staff
- Provide cleanroom cleaning, certification, garment service, disposable garments (shoe covers, gloves, etc.), new cleanroom design and construction consulting to Facilities, and more
- Collaborate with process CC engineers, PP scientists, missions and cleanroom managers and users

Best Practices and Protocols in Cleanroom Contamination and Biological Sensitive Spacecraft

Training and expertise

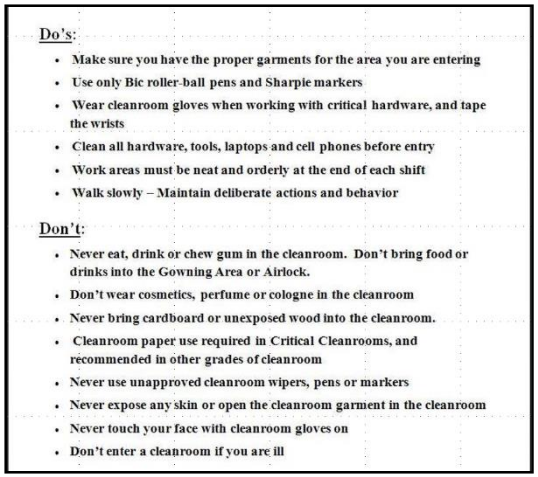


- TFM:
  - ISO 14644, IEST RP's, ASTM
- PP:
  - Biological contamination control
- JPL cleanroom managers, users
  - Cleanroom Fundamentals
  - Electrostatic discharge (ESD)
- Mission specific biological training
  - ATLO specific training (e.g. MSL, InSight)
  - Tailored, site specific training (e.g. Mars 2020 avionics)
  - Launch Operations training for project supporting personnel (e.g. InSight)

Best Practices for Biological Sensitive Spacecraft

"We are in this together"

- Training includes protocols for users
  - Know who to ask
  - Is a given material ok in the cleanroom?
  - Teaming



Do's:

- Make sure you have the proper garments for the area you are entering
- Use only Bic roller-ball pens and Sharpie markers
- Wear cleanroom gloves when working with critical hardware, and tape the wrists
- Clean all hardware, tools, laptops and cell phones before entry
- Work areas must be neat and orderly at the end of each shift
- Walk slowly – Maintain deliberate actions and behavior

Don't:

- Never eat, drink or chew gum in the cleanroom. Don't bring food or drinks into the Gowning Area or Airlock.
- Don't wear cosmetics, perfume or cologne in the cleanroom
- Never bring cardboard or unexposed wood into the cleanroom.
- Cleanroom paper use required in Critical Cleanrooms, and recommended in other grades of cleanroom
- Never use unapproved cleanroom wipers, pens or markers
- Never expose any skin or open the cleanroom garment in the cleanroom
- Never touch your face with cleanroom gloves on
- Don't enter a cleanroom if you are ill

In-class training is complete,

now what?

- Allowed items
  - Poster, list or pictorial
  - Lockers, hangers, etc.
- Commonly discouraged activities
  - Poster, list or pictorial

JPL Cleanroom Practices and Protocols

Communication Flow

- Communication - project to facility engineers.
- PP and CC engineering key.
- Planning, development and implementation.
- Timely communication of performance results for any adjustment.
- Establishing cleanroom working group.
  - Reporting activities daily.

JPL Cleanroom Practices and Protocols

Enhanced Cleanroom Protocols and Procedures

- Biologically sensitive missions:
  - CC, PP and TFM work concert, leading to:
    - Increased gowning protocols (e.g. full bunny suits and surgical masks required for ISO 8 processing.
    - Increased cleaning protocols (e.g. RO water, frequent changing of mop heads, proper wiping technique training).
    - Tighter controls in gowning room flow (e.g. gowning room personnel ingress).

JPL Cleanroom Practices

		Non Bioburden Mission	MER	MSL	InSight – Flight System, Denver, prior to 2016 storage
General Facility Considerations	ISO Class Assembly	8.5	8	8	8
	Bioburden Control Area	-	-	-	✓
	Utilization of Sporicide	-	-	-	-
Anteroom / Garment Prep	ESD-like shoe covers	-	✓	✓	✓
	Hairnet	-	✓	✓	✓
	Face Masks	-	-	✓	✓
	Surgical Face Masks	-	-	✓	-
	Street Clothes Allowed	✓	✓	✓	✓
	Cleanroom Underwear	-	-	-	-
	Personal Electronics Allowed	✓	✓	✓	✓
	Personal Hygiene Plans	-	-	-	-
	Medical Screening	-	-	-	-
Garmenting	Smocks	✓	✓	-	-
	Full Bunny Suits	-	-	✓	✓
	Show Covers	✓	✓	✓	✓
	Gloves	-	✓	✓	✓
	Taped Gloves	-	-	✓	✓
Processing of Hardware	Solvent Cleaning	-	✓	✓	✓
	Sterilized Tooling	-	-	-	-
Biological Performance	Average Spores m/2 on hardware surface	~1,600	74	36	124

JPL Cleanroom Practices and Protocols

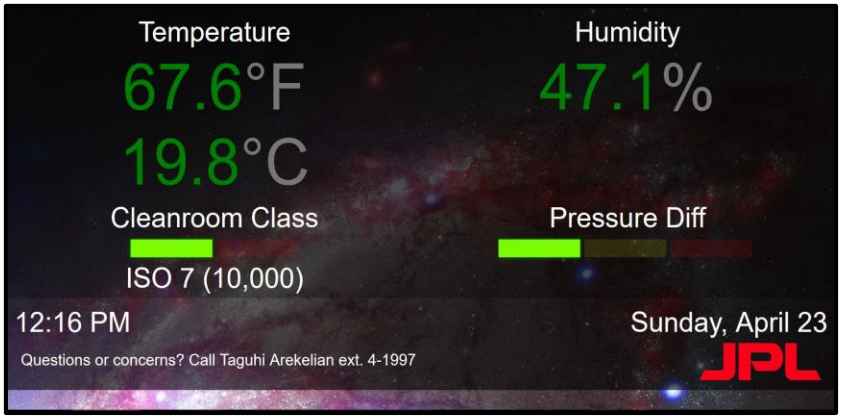
Cleanroom set-up

- Gowning room:
  - Shoe cleaners
  - Tack-mats
  - Defined dirty and clean sides
  - Gowning & de-gowning instructions
  - Cleaning supplies for small items
- Airlock
  - Defined dirty and clean sides
  - Cleaning supplies
- Air shower
  - Number of people allowed

JPL Cleanroom Practices and Protocols

Cleanroom monitoring

- Certification
  - Cleanrooms
  - Cleanroom HEPA vacuum cleaners
  - Frequency
- Remote continuous airborne particulate, temperature, relative humidity and differential pressure monitoring
  - Reduced frequency of certification
  - Reporting to customers



JPL Cleanroom Practices and Protocols

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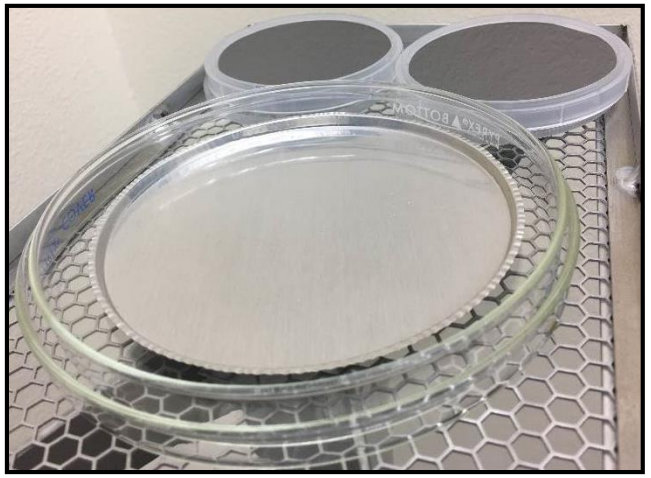

Table 1. Witness Plates - Low Volatility Residue Deposition

Sample	Chemical Functional Group	Total Amount (µg/cm²)
South East	AHC	< 0.02
North East Corner	AHC	< 0.02
North Middle Shelf	AHC	< 0.02
South Middle Shelf	AHC	< 0.02

Particle Size Range (µm) and Counts (per 0.1 m²)

Sample	5-15	15-25	25-50	50-100	100-250	250-500	500-750	750-1000	1000-1250	> 1250	PAC (%)	FPAC (%)	PCL
South East	211	30	0	0	0	0	0	0	0	0	0.00001	0	100
North East Corner	693	181	151	30	0	0	0	0	0	0	0.0002	0	200
North Middle Shelf	60	0	60	0	60	0	0	0	0	0	0.0009	0	300
South Middle Shelf	331	0	0	0	0	0	0	0	0	0	0.00002	0	100

JPL Cleanroom Practices and Protocols

Biological Cleanroom Monitoring

- Assessment by PP technical staff for biological requirements (e.g. ISO 8 = 1,000 spores/m^2 on surfaces and <88 cfu/m^3 for air) prior to hardware assembly/test and during the hardware processing.
- Additional assessments conducted during critical biological operations (e.g. spacecraft stack or more stringent hardware requirements)
- Anomaly testing conducted in the event of cleanroom procedure or process being compromised.
- Monitoring includes (refer to N. Benardini presentation)
  - Standard monitoring includes – surface sampling using wipes and air sampling (e.g. direct impaction onto plates)
  - Additional monitoring includes – rapid monitoring adenosine tri-phosphate (ATP) swabs, genetic inventory DNA signature mapping, and air sampling to include impingement into buffer solution for multiple analysis.

JPL Cleanroom Practices and Protocols

HEPA Filters

- Evaluated
  - Frequency
- Tracking air velocity through the filters
  - Frequency

Date	02/05/2016	8/3/2016	1/30/2017
HEPA #	Velocity	Velocity	Velocity
Bldg.#-Rm.#-001	99	97	101
Bldg.#-Rm.#-002	110	105	108
Bldg.#-Rm.#-003	107	99	103
Bldg.#-Rm.#-004	102	101	103
Bldg.#-Rm.#-005	98	99	98
Bldg.#-Rm.#-006	111	109	109
Bldg.#-Rm.#-007	93	98	94
Bldg.#-Rm.#-008	104	104	106
Bldg.#-Rm.#-009	97	101	100
Bldg.#-Rm.#-010	106	101	103
Bldg.#-Rm.#-011	101	102	103
Bldg.#-Rm.#-012	99	95	95

Rm. #1 | Rm. #2 | Rm. #3

System #	Facility ID or System with HEPA Filters	Effectively a Cleanroom Yes/No	Last Installation Date	Cleanroom Contact	Qty	Planned Total Cost $k	Risk Est	##### FY17 In Svc	Deferred ?	Previously Evaluated ?	Comments for Juan & Juan
1		Yes	5/15/09		26	$22.9	1	8	Yes	N/A	Replace January 2018 Go to building & investigate access to HEPA's
2		Yes	1/1/08		1		1	9		No	Unknown # of years in service, so evaluate annually until needs replacement
3		Yes	1/1/08		12		1	9		Yes	Unknown # of years in service, so evaluate annually until needs replacement
4		Yes	1/1/08		7		1	9		No	Unknown # of years in service, so evaluate annually until needs replacement
5		Yes	2/4/05		8	$5.6	1	12		No	Replace
6		No	8/16/06		1	$2.8	1	10		N/A	Replacing
7		Yes	5/7/07		8	$5.8	1	10		Yes	Evaluate soon
8		No	4/15/09		6	$4.6	1	8		Yes	Ignore
9		No	9/24/07		6	$4.6	1	9		Yes	Ignore
10		Yes	4/6/07		2	$3.1	1	10		Yes	
11		No	3/20/07		6	$5.0	1	10		No	Inactive
12		No	3/19/07		2	$3.2	1	10		No	Inactive
13		Yes	2/1/08		3	$4.9	1	9		No	Evaluate
14		Yes	4/1/08		1	$2.8	1	9		N/A	Ignore
15		Yes	4/1/08		1	$2.8	1	9		N/A	Ignore
16		Yes	9/22/06		6	$5.1	1	10		N/A	Ignore
17		No	9/18/07		1	$2.7	1	9	Yes	N/A	Cassini project ends this year
18		Yes	8/15/06		94	$45.7	1	10	Yes	N/A	Can't replace until FY18
19		No	6/1/08		8	$6.0	1	8	Yes	N/A	Can't replace until FY18
20		Yes	6/8/07		1	$2.7	1	9		N/A	Ignore
21		No	9/29/08		108	$52.2	1	8		N/A	Ignore
22		Yes	6/1/08		8	$6.0	1	8	Yes	N/A	Can't replace until FY18
23		Yes	6/1/08		3	$3.7	1	8	Yes	N/A	Can't replace until FY18
24		Yes	5/30/07		3	$3.5	1	9	Yes	N/A	Can't replace until FY18
25		Yes	5/25/07		1	$3.2	1	9		Yes	Evaluate
26		Yes	3/13/09		2	$3.3	1	8		Yes	Evaluate
27		No	8/25/06		28	$15.3	1	10		Yes	On hold, waiting on longevity
28		No	11/29/06		1	$2.8	1	10		N/A	On hold, waiting on longevity
29		No	3/26/07		8	$11.7	1	10		N/A	Ignore
30		No	3/11/09		6	$5.9	1	8		No	Evaluate
31		Yes	2/5/09		654	$293.7	1	8		N/A	Begin evals FY18
32		No	2/10/09		1	$2.8	1	8		No	Evaluate
33		No	2/11/09		1	$2.8	1	8		No	Evaluate
34		No	2/12/09		8	$6.2	1	8		N/A	
35		No	9/23/08		12	$7.4	1	8		N/A	
36		No	3/8/07		1	$2.7	1	10		N/A	
37		No	4/27/07		1	$2.8	1	10		N/A	

... | FY17 AHU Plan for Techs | FY17 Plan for Techs | Planned vs Actual Systems & Fil | FY17 Large Installs Plan | FY17 End of Year Installs | Service Orders | Ser

JPL Cleanroom Practices and Protocols

Challenges

- ESD materials and contamination control in cleanrooms
  - Always searching for materials that particulate and outgas less
  - This increases cost, sometimes to unacceptable levels
- Relative humidity control
  - Not all air handlers are able to keep up with Southern California warm and dry days

JPL Cleanroom Practices and Protocols

Questions?

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